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FOREIGN TECHNOLOGY DIVISION

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EXPERIMENTAL INVESTIGATION OF THE DESTRUCTION OF ThF_4 PROTECTIVE FILM BY A PULSED CO_2 LASER

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Currently, gold film reflectors are commonly used in high power /57
CO_2 laser resonance chambers and focusing systems. Gold-film reflectors are soft and easily soiled. They are easily damaged when cleaned and scratch marks frequently appear, so that the optical qualities of the reflector are affected.

In order to find a suitable protective film for gold-film reflectors, the Heilongjiang Technical Physics Institute has plated gold-film reflectors with ThF_4 protective film. Experiments demonstrate that the /58
film possesses qualities that may overcome the defects mentioned above.

The optical films used in laser systems must possess not only the quality of high mechanical scratch-proof and erosion-proof capabilities, but also that of high laser-damage-prevention ability, i.e., high damage threshhold. This is very important for prolonging laser lifetime and insuring good optical qualities.

Although the gold film's mechanical properties are enhanced by the ThF_4 protective film, will the ability to prevent laser damage of the gold film be maintained? This is a question concerning the user. For this purpose, we have carried out some experimental investigations on the laser-damage prevention ability of glass-based and copper-based gold film reflectors after being plated with the ThF_4 protective film. In the experiment, samples are irradiated with a CO_2 pulse laser of wave length of 10.6 micron (pulse width is 0.6 microsecond) at 4 different energy densities: $1.2X10^6$ watt/cm^2, $2.4X10^6$ W/cm^2, $2.7X10^6$ W/cm^2 and $35X10^6$ watt/cm^2. The damages are observed and analysed microscopically.

1. EXPERIMENTAL SET-UP

A double-discharge CO_2 laser made in the Mechanics Institute is used in the experiment. The output energy is measured with a carbon energy meter. The output energy is focused with a germanium lens with a focal length of 100mm onto the sample (the germanium lens is coated with a transmission enhancing film). The beam spot shape is displayed by shining the laser beam on carbon paper. The spot area is determined with a microscope and the following formula is used to calculate the power density

$$I = \frac{E}{S\tau}$$

where E is the laser energy output, S - the beam spot area, and τ the pulse width. The experimental set up is shown in Figure 1.

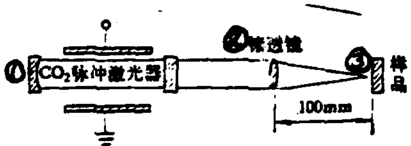

Figure 1. Diagram for the Experimental Set Up.

Key: 1--CO_2 pulse laser; 2--germanium lens; 3--sample.

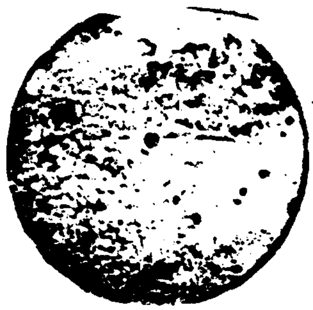

Figure 2. K_8 glass Cr/Au power density $1.2X10^5$ W/cm^2 Enlarged 26 times.

Figure 3. K_8 glass $Cr/Au/ThF_4$ power density $1.2X10^6$ W/cm^2 Enlarged 26 times.

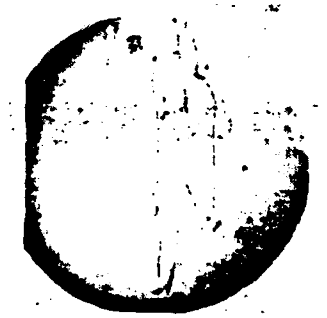

TABLE 1. Tabulated Experimental Set Up

Base Material	Film Plated	Observed Result			
		1.2×10^6 W/cm^2	2.4×10^6 W/cm^2	2.7×10^6 W/cm^2	3.5×10^6 W/cm^2
K_8 glass	Cr/Au	There is directly observable damage on the irradiated surface. The glass base is observed to have cracked under microscopic observation as shown in Figure 2.			
K_8 glass	Cr/Au/ThF_4	The ThF_4 film is damaged on the irradiated surface. The film and the base are torn in layers as shown in Figure 3.			The degree of damaged increases but, is less than that at 1.2×10^6 W/cm^2 irradiation without the ThF_4 protective film on the gold film, Figure 4.
Copper	Cr/Au	The film on the irradiated surface is not damaged.	The film on the irradiated surface is damaged. The base has cracked as shown in Figure 5.		
Copper	Cr/Au/ThF_4	The film on the irradiated surface is not damaged.	The film on the irradiated surface has no directly observable damage.	The ThF_4 film on the irradiated surface has begun to crack as shown in Figure 6.	The ThF_4 film on the irradiated surface melts and wrinkles as shown in Figure 7.

 

Figure 4. K_8 glass Cr/Au/ThF_4 power density 35 x 10^6 W/cm^2 enlarged 20 times.

Figure 5. Copper base Cr/Au power density 2.4 x 10^6 W/cm^2 enlarged 20 times.

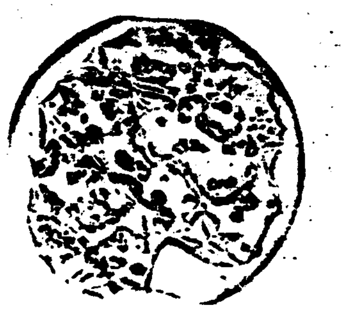 

Figure 6. Copper base Cr/Au/ThF_4 power density 2.7 x 10^6 W/cm^2 enlarged 20 times.

Figure 7. K_8 glass Cr/Ag/ThF_4 power density 35x 10^6 W/cm^2 enlarged 20 times.

2. EXPERIMENTAL RESULTS

From the above mentioned experimental results, we can see that there is a great difference in the degree of damage for mirrors of K_8 glass base plated respectively with Cr/Au and Cr/Au/ThF_4 films under 1.2 x 10^6 W/cm^2 power density irradiation. The reflector base without the ThF_4 film has already cracked while for the mirror with ThF_4 film, only the surface film is damaged. Even under the power

density of 3.5×10^7 W/cm^2, only the ThF_4 film starts to melt and crack for reflector with ThF_4 film.

The reflector with copper base plated with Cr/Au gilm under 2.4×10^6 W/cm^2 not only has the film damaged, but the base has also been observed to crack. However, at the same power density, the mirror plated with ThF_4 protective film has no directly observable damage. When the power density is 2.7×10^6 W/cm^2, the ThF_4 film begins to crack and flake. Only until we reach 3.5×10^7 W/cm^2 does the ThF_4 film start to melt and wrinkle.

3. CONCLUSION

(1) Experimental analysis indicates that the damages on the ThF_4 film are mainly the layering, cracking and melting due to thermal effect.

(2) Plating with the ThF_4 protective film improves not only the anti-mechanical scratch and anti-erosion ability of the gold film reflector, but also its ability to prevent laser damage.

(3) The experimental result indicates that the damage threshhold of the ThF_4 protective film is between $10^6 - 10^7$ W/cm^2. This result agrees with the research result of ThF_4 protective film on silver-plated reflector in reference [1].

REFERENCES

[1] Wang, V.., et al, Laser induced Damage in optical materials, 183 (1972).

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